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AN OUTLINE OF THE DEVELOPMENT OF A CHIMÆROID.

BASHFORD DEAN.

The common chimæroid of the west coast of the United States, *Chimæra collieri* Jenyns, was taken in deeper water (50–150 fathoms, sp. gr. 1.027, 55° F.) off the Californian coast and in shallower (5–20 fathoms) in Puget Sound. Near Monterey, in water of about 100 fathoms, eggs about to be deposited were taken from females and incubated in sunken cases; by this means a fairly representative series of embryonic stages was secured.¹ In addition one embryo was obtained from an egg-case taken accidentally on the hook of a trawl line, and a series of hatched young were kindly placed at the writer's disposal by the U. S. National Museum.

Spawning occurs at Monterey throughout spring, summer and fall, and a few eggs were obtained by the Chinese fisherman Ah Tack Lee during the winter. The period of maximum spawning is during August. Two eggs are deposited at the same time. And for several hours at least, at the time of protrusion, they hang freely in the water, the small end of each egg-case attached close to the genital opening. The case here terminates in a single string-like process which passes up the oviduct as far as the capsular gland, and here it is so firmly attached at this stage that it can be lengthened—to the degree of several inches—and shortened like a strand of gutta-percha. Exactly how the egg is deposited is unknown; in any event it appears to be

¹ The writer is greatly indebted to President Jordan and to the directors of the Hopkins Seaside Laboratory, at Pacific Grove, for many courtesies extended him during two summers at the laboratory; and to Dr. Ray L. Wilbur for much generous and skilful coöperation in securing material from the Chinese fisher-people during the years 1897, 1898 and 1899. Dr. Wilbur made numerous trips from San Francisco to Monterey during this time, and to his interest in my work and to his boundless energy I am indebted for many of the later and rarer stages of this interesting fish. To Ah Tack Lee, most skilful and intelligent of local fishermen, I owe my best thanks for his services as a collector. To Mr. Naohidé Yatsu, finally, for much valuable assistance in connection with the preparation of the present paper. His are the drawings from which Figs. 8–12, 17–19 are reproduced.

at first attached to stones, etc., by a bulbous tip at the end of the string-like process of the egg-case.

Copulation takes place shortly before the eggs are deposited, for females with eggs in oviducts are usually found with recent marks of the prehensile organs of the male. That the male twists about the female, shark-like, is evident from the character and nearly uniform position of scars near the base of the dorsal fin of the female. These markings, corresponding with the denticles of the frontal organ, indicate that the pair are locked together in copulo. Both mixipterygia appear to be inserted.

There is evidence from experiments with gravid fish kept in aquaria that the elaborate egg-case (Fig. 1) takes but a short time to be formed, possibly not longer than three days. The dilated portion of the case is laid down and is almost perfect, including the lateral processes before the stalk appears; during this time the lining of the oviduct becomes curiously developed to produce the highly specialized structures of the case. The exit-slit or "door" is formed by an abrupt folding in the case's wall. In this folding there is a double row of transversely-directed, interlocking

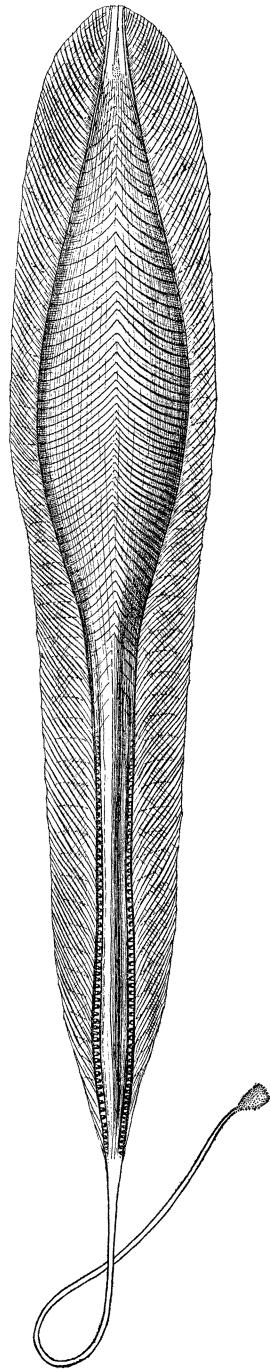
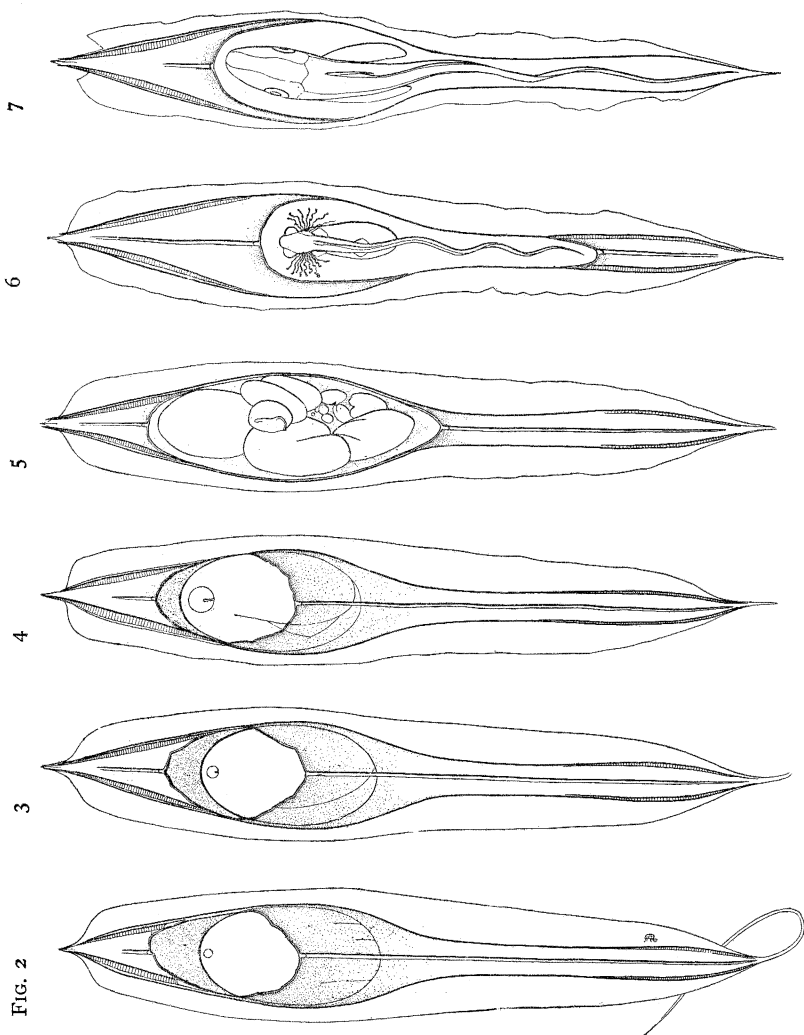


FIG. 1. Egg-case of *Chimæra collii*. 'Ventral' aspect. $\times 1$. The case is of extraordinary length (about seven inches to the base of the terminal filament) compared with the total length of the female (about twenty-three inches). The egg itself when freshly deposited is elongate and depressed (about $1\frac{1}{8}$ in. \times $\frac{3}{4} \times \frac{1}{2}$ inches), after the fashion of elasmobranchs. It is of similar syrupy consistency, flowing away as soon as the vitellina is ruptured.

FIG. 1.



FIGS. 2-7. Characteristic stages in the development of *Chimæra*. These are shown in the opened egg-capsules and represent (2) late blastula, (3) gastrula, (4, 5) two stages of early embryos, (6) a late embryo, and (7) a young fish about to escape from the capsule. The retarded segmentation of the egg is indicated in Figs. 2-5, but in the three earlier stages the cleavage lines cannot be seen through the wall of the egg-capsule (as has been indicated diagrammatically).

lamellæ, and around their delicate tips the thin walls of the shell weather away so that, by the time of hatching, the interlocking¹ lamellæ can disengage and thus permit the young fish to push its way through the folds. The exit-slit of the egg-case is thus a line of rupture. By somewhat similar lamellæ framing a bilateral series of fenestræ ventilation within the case is obtained and perfected in later stages. The fenestræ (as in eggs of certain elasmobranchs) occur in the hinder end of the case, and in latest stages water flows through them, a current being created by the constantly undulating tail of the embryo. The latter has at all times a highly specialized relation to the egg-case, as is indicated in Figs. 2-7. As soon as the embryo can be determined its head points toward the opening-end of the case, the keeled side of the case being dorsal. It is evident that the narrow end becomes the neatly fitted sheath for the elongated tail, and that the widened end fits accurately the greatly enlarged head and trunk. The young hatches as soon as the straight egg-case is filled; thus there is no coiling and wrapping up of the later embryos, as is found, for example, in the case of many sharks.

The Duration of Development.—After the egg is deposited (water temperature 50°-60° F.) fertilization stages continue for about twenty-six hours. If, therefore, we assume that the formation of the egg-case began with fertilization the total duration of this process is probably not less than three days, and not longer than five.

Segmentation (of nuclei), beginning about twenty-six hours after the egg is deposited, lasts from three to four days, each earlier cleavage taking about two hours.

A well-marked blastula is 110 hours old (Fig. 2).

Gastrulation dates from about the eighth day. On the tenth day the embryo resembles Balfour's stage *C* (*Pristiurus*) (Fig. 3); on the seventeenth, *D*; on the nineteenth, *E*; and on the twenty-second, *F* (Fig. 4).

Of later embryos one resembling stage *I* is thirty-one days old (Fig. 5). I have no accurate data of older stages. Assuming,

¹ A row is made up of two sets of interlocking elements, one passing to the right, one to the left, like fingers of interlocked hands.

however, a rate of development proportionate with that of known egg-depositing elasmobranchs I infer that an embryo of five inches can hardly be younger than nine months (Fig. 7). An estimate of a total incubation of twelve months in this species would hardly be excessive.

Fertilization.—Fertilization is shark-like. Polyspermy occurs and a similar number of merocyte nuclei; the conjugation of the pronuclei occurs at a similar niveau in the germinal area, the male pronucleus passing through the germinal protoplasm and then approaching the female pronucleus from a lower plane. Also similar are the location and behavior of the merocyte nuclei during early cleavages. Different from shark, however, is the longer duration of the period of the entrance of the sperm (a newly-entered spermatozoön being present in a preparation showing fusion of pronuclei), and the clearness with which sperm paths are to be noted. Of the latter the surface pits can be seen under low powers. The germinal area is also notably deeper than in the shark.

Segmentation.—As in *Torpedo* (Rückert) and certain other elasmobranchs the appearance of cleavages at the surface of the germinal area is retarded, the first surface furrow appearing about the time of the third or fourth nuclear division. In connection with the furrows at their deeper rim are vacuoles (as in Fig. 8

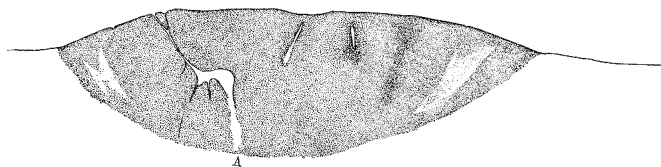


FIG. 8. Early segmentation. Section through middle of germinal area. At *A* a fissure-like vacuole becomes continuous with an intercellular space. \times about 30.

at *A*) which pass into the yolk, and suggest a former condition of deeper cleavage. This inference that the fissure-like vacuoles are to be interpreted as potential but semi-suppressed cleavage spaces is well borne out by the structures of a later stage (Fig. 9) in which the vacuoles are shown to be patently continuous with intercellular spaces, and in which nuclei occur in the underlying germinal masses. It is also to be inferred that a further degree

in the suppression of these vacuolar cleavage spaces would result in a homogeneous and nucleated subgerminal zone. Indeed, in the present material the vacuoles do disappear from the subgerminal zone (Figs. 10 and 11), although they appear as before at the side of the germinal area, and below it, separating masses of the yolk. Note also in this connection the presence

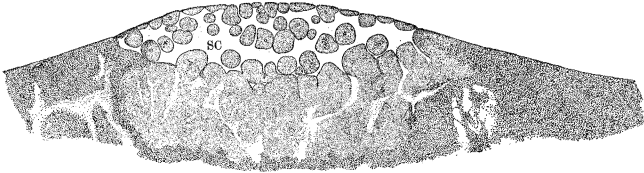


FIG. 9. Early blastula. Vacuoles are shown, continuous in arrangement with cleavage spaces. SC. Early segmentation cavity.

of nuclei in the marginal yolk masses thus separated as below the marks * and *, two points in the section, Fig. 11. And in another stage, Fig. 10,¹ it will be seen how far peripherad these nuclei can be traced, *e. g.*, at the points I., II., III., IV. and V. — as far peripherad, in other words, as this region of the egg has been sectioned. It follows accordingly that the yolk mass is separated from the germinal region by no means as abruptly in *Chimæra* as in the allied sharks. For in *Chimæra*,

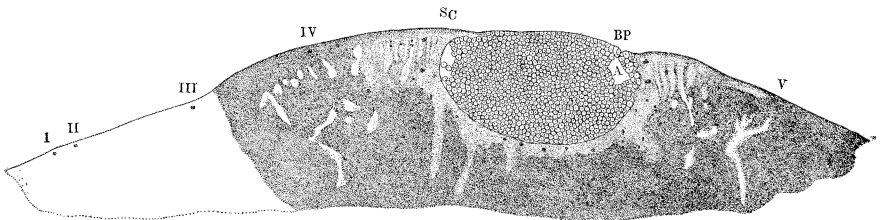


FIG. 10. Early gastrula. Sagittal section. A. Archenteron. BP. Blastopore. SC. Segmentation cavity. I-V. Nuclei lying outside of the germinal area.

as we have seen, vacuoles which in some cases at least represent intercellular spaces pass deep into the yolk region, in the form of more or less vertical fissures. Moreover, again unlike sharks, the yolk nuclei which surround the margin of the germinal area

¹ On one side of the present section nuclei I. and II. occur in the eighth section, and III. and IV. in the seventh and sixth sections respectively; on the opposite side nucleus V. occurs in the fourth section.

do not occur throughout a narrow zone but extend peripherally over a wide area of the yolk. In connection with this remark-

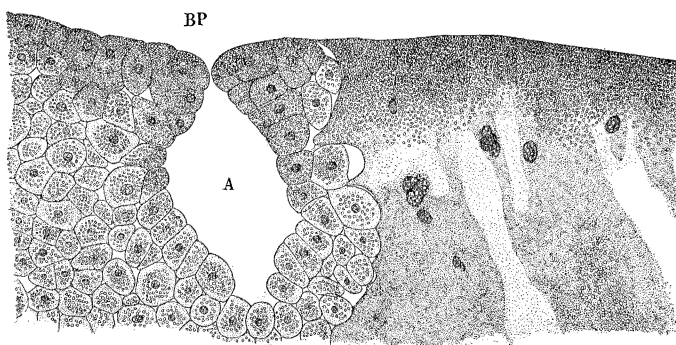


FIG. 10 A. Detail of archenteric region of preceding section.

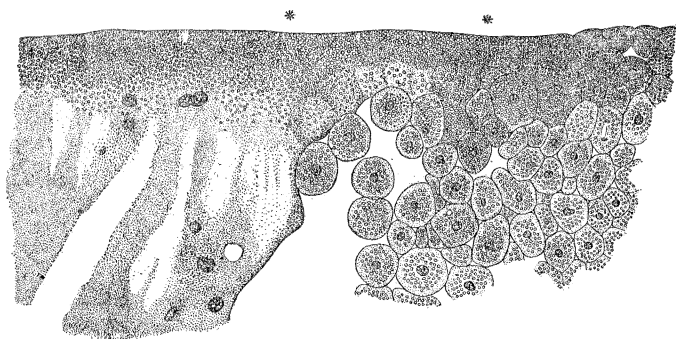


FIG. 10 B. Detail of antero-dorsal germinal wall of preceding section. Observe the cells arising in the overhanging germinal wall below and between the points *—*.

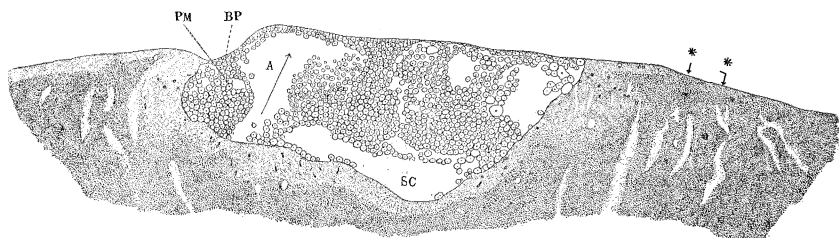


FIG. 11. Early gastrula. Sagittal section. A. Archenteron. BP. Region of blastopore. PM. Posterior cell mass (= ventral lip of blastopore). SC. Segmentation cavity. Yolk nuclei are below the asterisks. The arrow denotes the general axis of the archenteron.

able vacuolization of the yolk mass the extension of the nucleus-bearing zone is to be considered *a process of actual fragmentation*

of a large part of the entire egg, a process unique among vertebrates, and suggesting only remotely a physiological parallelism with developmental features in certain lower forms, *e. g.*, digenetic trematodes. Thus in a stage of late blastula the surface view of the egg (Fig. 13), shows with the unaided eye a distinct fissure

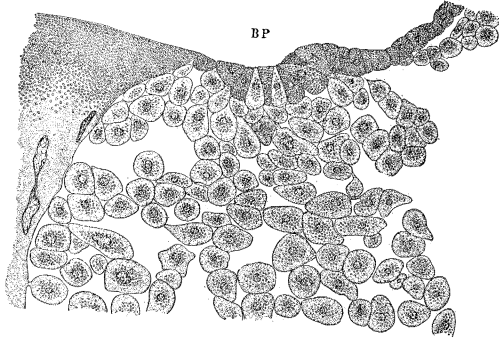


FIG. 11A. Detail of the region of the blastopore of Fig. 11.

passing near the side of the egg, between the points * and *, and into this run smaller ones.

That this is a fissure and not merely a surface marking becomes clear when the egg is hardened (*e. g.*, in corrosive-acetic), for the sides of the fissure then separate so that one can see between

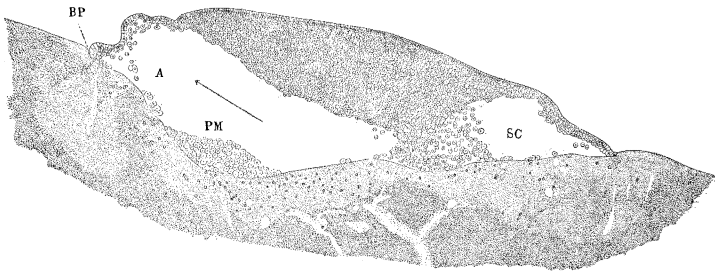
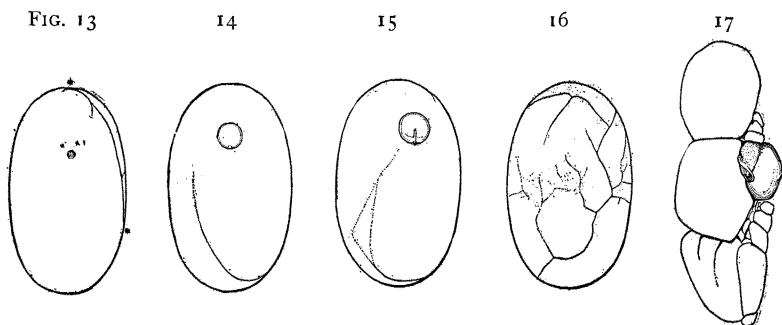


FIG. 12. Later gastrula. Lettering as in foregoing figure.

them deep into the yolk. In later stages (Figs. 14 and 15) similar conditions maintain, the fissures in these cases, however, extending outward from near the germinal region. In these cases it is found that the ventral side of the egg becomes more completely fragmented than the upper; thus the ventral side of the stage of Fig. 15 shows a variety of surface furrows (Fig. 16),

which by hardening appear as edges of deep fissures. So deeply indeed do these pass into the yolk that the writer was able by means of needles to remove a yolk mass—that lying in the middle of the lower half of the figure—almost entire. This mass, however, broke down in the process of further hardening, and no sections of it could be prepared. In later stages (Figs. 5 and 17) fragmentation continues still further. The embryo with its circumcrescent blastoderm is now attached to a relatively small portion of the yolk; the remainder is broken up into masses, big and little, and in the living egg the smallest are found dissolving into a pasty or creamy liquid, which at first sight is apt to hide the embryo and lead the observer to believe that the egg is dead and addled—an impression he soon loses when he dis-



FIGS. 13-17. Eggs showing the progressive cleavage of the yolk mass. In a blastula (13) a conspicuous fissure is noted between the points * and *. In an early gastrula (14) a fissure extends hindward from near the rim of the blastoderm. In a later stage (15) a progressive fissuring of the yolk mass is seen, anteriorly and posteriorly, and notably in the ventral region (16). In the stage of Fig. 17 the entire yolk mass has undergone division, the blastoderm appropriating a single mass (slightly shaded in the figure).

covers a moving embryo and finds that the fluid is odorless. In ascertaining this the writer may mention, parenthetically, that he was on the point of losing one of his most valuable stages. An egg-case was brought in which had been taken by accident, having become entangled in a trawl line; it was light in weight and its general appearance of wear and tear indicated that it was an empty shell; it was opened, however, and showed a milky fluid which suggested, by analogy of shark eggs, an unpleasantly late stage in decomposition. But as the writer began to pour out the contents of the case carelessly, he saw to his surprise a

mass of bright red gill-filaments. The embryo itself next appeared, as shown here in outline in Fig. 6. It was taken to the laboratory and kept living for half a day; and possibly, like kindred shark embryos, it would have thriven for weeks had one decided to rear it. Corresponding to the mass of yolk attached to the embryos in Figs. 5 and 17, the older specimen had a yolk sac of remarkably small size; the sac was complete, however, and its vitelline circulation resembled closely that of a shark. Furthermore, it may be noted that a young *Chimæra* when newly hatched has no trace of an external yolk-sac. I should record, in this connection, that my friend, Dr. Wilbur, had already (1898) observed on several occasions that the embryo with its blastoderm appropriated only a portion of the entire egg mass, and that the yolk sac was but a miniature of a shark's. He then believed, like myself, that such a remarkable condition was abnormal. If a normal condition, however, the small yolk-sac and the fragmental yolk bear evidently upon the question of the total segmentation of this yolk-filled egg. And if the evidence is conclusive which the present observations afford, there is here given the first example of a large egg to undergo holoblastic cleavage—an interesting denial of the corollary of 'Balfour's law,' that the quantity of yolk present in an egg determines its holo- or meroblastic character. It may be well, therefore, to review in this connection the evidence of total cleavage in *Chimæra*. (1) The entire egg undergoes a progressive fragmentation, in course of which fissures first pass from the germinal region downward, and finally divide up the egg into a series of yolk masses. (2) The foregoing process is a normal one, having been observed in all specimens (later stages) examined—a dozen or thereabouts. (3) On the evidence of earlier stages distinct fissures (vacuolar) come to be formed in the sub- and circum-germinal yolk, and these are shown to be in many cases continuations of intercellular spaces of the germ itself. (4) The yolk tracts separated by (vacuolar) fissures contain nuclei; this we may conclude from the conditions pointed out in Figs. 10, 10A, and from the presence of nuclei far out beyond the germinal area (Fig. 10). In short, the egg actually undergoes total division, following a nucleation and fissuring of

its yolk-substance. There is of course still the possibility that this total division is not the equivalent of total cleavage in other vertebrates, for it may be due to the action of sperm nuclei — a possibility which finds some support in the subsequent history of the extra-embryonic yolk masses (*v. infra*). This problem, however, cannot be considered specifically at the present time.¹

Blastula. — A blastula in an early stage is drawn in section in Fig. 9. It shows a mass of blastomeres loosely arranged upon a basis of germinal cytoplasm, traversed by extensive intercellular spaces, the largest of which, *S. C.*, appears by comparison with later stages to represent the cleavage cavity. The topmost blastomeres are closely arranged and somewhat epithelial in character; the lowest are arising from the subjacent germinal well. Particularly interesting is the fissuring (vacuolar) of the subgerminal cytoplasm and of the neighboring yolk, for many of these fissure-like vacuoles are seen to be directly continuous with intercellular spaces, and are, as has above been noted, best interpreted as suppressed (or, better perhaps, retarded) lines of cleavage. Asymmetry is already present in this stage, for it will be seen that upon one side of the figure the blastomeres abut directly against the yolk, and that a more rapid increase in cells is taking place nearer the opposite side of the blastula.

Gastrula. — In Fig. 10, a section in which blastopore and archenteron appear, is represented one of the most valuable stages in my material, for I believe it furnishes us the key to the problem of the gastrulation of *Chimæra* and also probably of sharks. It shows in median section a dense mass of cells lying deep within the germinal area, and closely apposed, save at one point, (anteriormost) to the subgerminal cytoplasm. Near the opposite (posterior) rim of the cell-mass, near the surface, is a small cavity, Figs. 10 and 10 A, *A*, which communicates with the sur-

¹ Another problem which must here be neglected deals with the important relation of yolk nuclei to mesenchyme. In this matter one may note, however, that *Chimæra* confirms Rückert's position as to the conditions in sharks. The confirmation is especially striking, since the additions to the mesenchyme budded out of the germinal wall are here of gigantic size, and cannot be confounded with the neighboring mesoblast cells.

face at the pore, *BP*. Behind it, *i. e.*, between it and the yolk, lie several rows of cells. In this cavity and its surface opening, then, we recognize archenteron and blastopore, and note further that the peculiar pigmentation of the cells of the surface of the gastrula can be followed down on either side, suggesting recent invagination, into the archenteric cavity, half way to its bottom. This, therefore, we conclude, is not a mere intercellular space with a fortuitous opening to the surface, but a definite cavity, whose cells lining the outer half are pigmented. Its cellular wall, moreover, is in general firm and compact, epithelial in character. Accordingly we must admit that in *Chimæra* a gastrula is formed whose blastopore is located not *at* the rim of the early blastoderm but *near* it. And it follows that in this condition there is still retained a phylogenetic stage in elasmobranchian gastrulation wherein the merging of the blastoderm cells into the surrounding yolk has not yet extended to that zone of the blastoderm where the blastopore is forming. It will be observed that growth is taking place at both anterior and posterior margins of the present blastoderm. Cells are coming to be budded off behind the archenteron, as well as at the blastoderm's anterior rim (Fig. 10 B) within the overlying germinal wall itself (*v.* between the points * and *). And even at this late stage blastomeres are found to be budded off abundantly from the subgerminal wall. One notes, further, that the cavity at *SC*. enlarges considerably on either side of the median line and is obviously interpreted as the segmentation cavity. In this stage many merocytes and sperm nuclei occur in the germinal wall.

In Fig. 11 is shown a somewhat later gastrula. Here the compact character of the former stage is lost, the diameter of the blastoderm having doubled. In the anterior region the segmentation cavity, *SC*., is enlarged and is many-branched. The blastopore is obliterated, owing probably to the backward growth of the cells at the surface of the blastoderm; the archenteron, on the other hand, was greatly increased in size; its anterior wall, spreading out into a thin, somewhat epithelial layer, forms its roof, and its fundus is made up of loose cells, which focus together anteriorly. Behind the archenteron is a mass of cells, *PM*., read-

ily identified with that in the earlier stage. In an adjoining section, of which a detail is given in Fig. 11A, a rudiment of the blastopore of the earlier stage is shown in the region *BP*.

In a still later gastrula, Fig. 12, the prominent feature is the growth of the blastoderm hindward. The blastoderm has now increased its diameter by about one third, and its surface growth has outstripped that of the subgerminal region—in spite of the fact that the subgerminal wall has notably flattened. Thus it has come about that the posterior region of the blastoderm of the earlier stage has rolled over, as it were, the neighboring germinal wall. The point indicated at *BP*. has thus come to lie first at the edge of the blastoderm, and is next passed under its rim. And as at this point of “invagination” a separation of the cells now occurs, *this may be taken as the reopening of the blastopore*. With this rapid hindward growth the mass of cells, *PM*., is seen to take a position apparently far forward on the subgerminal wall, but it remains in reality in its previous relative position (*i. e.*, it retains the same actual distance from the anterior border of the blastoderm). Connected again with this backward growth of the surface of the blastoderm it is also evident that the general lie of the archenteric cavity has changed, its anterior end having now been carried backward, its main length (axis of cavity) rotating somewhat as denoted by the arrows in the figures. Other symptoms of the rapid growth of the posterior rim of the blastoderm are seen in its closely compressed cells, epithelial, and in its crumpled condition. Noteworthy, further, is the solidness of the mass of cells roofing the anterior portion of the archenteron, and the reduced size and clearer contour of the segmentation cavity. It will be observed that in this stage the conditions are closely similar to those of the shark, excepting only that the archenteric and segmentation cavities have not clearly merged.

Early Embryos.—Early embryos resemble closely those of typical elasmobranchs (*cf.* Figs. 3, 4, 15); the entire extent of of their surrounding blastoderm, however, is much smaller, and the embryo attains a large size before the adjacent blastoderm surrounds a small mass of the yolk (about three eighths inch in diameter). Stages occur resembling closely sharks in Balfour's notation *C*, *D* and *E*. One might note that the head folds in the

later stages are not as conspicuous. In Fig. 18 is shown a section of an embryo of about stage *C*, which is readily comparable with a corresponding stage of *Torpedo*, as figured, for example, by the Zieglers (*Arch. f. mikr. Anat.*, XXXIX., pl. IV., Fig. 19, VI.); an interesting difference is the depth to which the sub-blastocoelic entoderm passes into the germinal yolk at the sides of the gut, a feature which might indeed have been expected in this type of egg. In this connection observe also the fissuring (vacuolar) of the germinal yolk.

Late Embryos.—Embryos of about one eighth inch in length can be readily distinguished from those of sharks. The shape of the head is alone distinctive, for the forebrain vesicle sprouts out like a knob or crest and is a feature characteristic of embryos

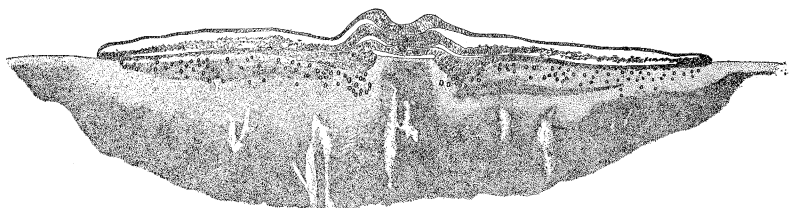


FIG. 18. Gastrula. Section through the embryonic region of the stage shown in Fig. 14.

up to about three fourths inch in length. Other characteristics are the long delicate tail and the short yolk stalk. In still later embryos external gills are developed, in a very shark-like fashion. A spiracle is present in as late a stage as one and a half inches; it is then a delicate tubular structure and is unprovided with external filaments. Peculiar to the latter is the presence of dilatations, or blood knots, about $\frac{1}{140}$ inch in diameter, brilliantly conspicuous by their scarlet color and large size in the living young. They are doubtless places of multiplication (judging from numerous mitoses) of red blood corpuscles. In this stage, as already stated, the embryo is surrounded by a milk-like fluid, which can only be derived from the continued breaking down of the separate yolk masses of an earlier stage (Figs. 5, 13-17); that it is nutritive there can be no doubt, and there is every reason for believing, judging from the physiological characters of the young of other

elasmobranchs, that it is taken up by the embryo. It is probable that it is appropriated *via* gills (which may become trophone-mata, as shown by Wood-Mason, Alcock, Haswell and others), and gut. This stage is of further interest from the standpoint of the morphology of the chimæroid head, for it demonstrates that the autostylous character of the skull is secondary, as had indeed been surmised from the time of Johannes Müller. As indicated in Fig. 19, from a drawing of a wax-plate model,

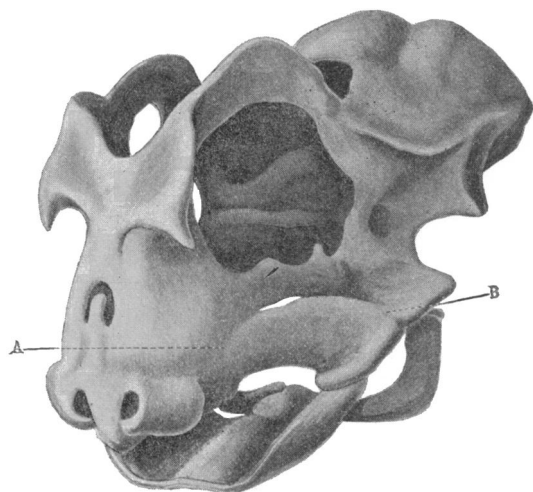


FIG. 19. Skull of embryo shown in Fig. 6. After wax-plate model. The palato-quadrates is shown fusing with the cranium at the points *A* and *B*.

the skull in this stage shows the upper jaw (palate-quadrates) still separate, although even at this early stage its fusion with neighboring cranial cartilage is taking place at both its anterior, and posterior borders, *A*, *B*. Conspicuous in all early stages is the disproportionate size of the anterior and posterior body regions; head and anterior trunk are large, posterior trunk and tail dwindle away narrowly, the latter, however, attaining extreme length. These characters, together with the great size of the eyes in embryonic stages, are clearly in the line of preparing the young fish for the conditions of deep-water living.

Conclusions.—The mode of development of *Chimaera* affords evidence, I conclude, in support of the following theses.

I. That sharks and chimæroids are closely related geneti-

cally. Thus in comparison with other piscine groups, they are allied with one another much as earliest ganoids with the teleosts. Taxonomically we have therefore to revert to Bonaparte's early arrangement (of about 1840) and regard elasmobranchs as a subclass, and selachia and holocephala as natural orders (or super-orders).

II. That in some regards, in comparison with selachians, the chimæroid has retained the more primitive developmental features, *e. g.*—the total segmentation of the egg, and the less modified early gastrula. That in other respects it has acquired more highly specialized characters, *e. g.*, restriction of the blastoderm to a smaller region of the egg, appropriation of yolk *via* the external gills (and gut), extraordinary egg capsule and its adaptation to the embryo. (The foregoing conditions, wherein high specialization is found associated with archaic developmental processes, are essentially in keeping with our knowledge of the history of the chimæroid group as derived from anatomy and palæontology. Descended from earliest sharks, this group may well have retained some of their peculiar developmental characters, *e. g.*, in earlier stages; on the other hand new and modified processes of growth doubtless arose in connection with advances which were taking place in the special direction of chimæroid structures.)

III. Of more general significance, I believe, are :

(A) The early processes of gastrulation in *Chimæra*, which elucidates the corresponding developmental stage in sharks. In these forms, long studied among vertebrates, gastrulation has been subject to widely different interpretations—indeed in the latest time so careful an observer as Samassa has *even denied the presence in sharks of any process of gastrulation sensu stricto*. *Chimæra*, it now appears, indicates that the blastopore of sharks is a secondary structure.

(B) The accessory mode of nutrition of the late embryo. In sharks the yolk is appropriated by means of a constant extension of the blood-producing area and a progressive differentiation of the vitelline circulation. In *Chimæra*, on the other hand, this mode of nutrition of the embryo is less extensively established, for it has been supplemented by the fragmentation of the yolk

and its appropriation by external gills¹ (and gut). This process is an important one from a larger aspect since it yields a mode of nutriment hitherto unknown in vertebrate embryology—a process by which a late embryo appropriates as food, in the ordinary acceptance of the term, an outlying portion of its own organism.

(C) The mode of development of mesenchyme from yolk-nuclei in a somewhat similar way as described by Rückert for selachians.

¹ The origin of the latter process is suggested on the following lines : The gills lying in close contact with the egg came to absorb nutriment from the neighboring finely divided blastomeres and from the interblastomeral fluid. And the embryo came to employ the peripheral yolk more promptly and efficaciously thus than in the ancient way, with the result that the peripheral blastomeres became more loosely associated and finally separated. These melt ultimately into a creamy fluid especially adapted for providing nutriment for the specializing gills of the embryo.